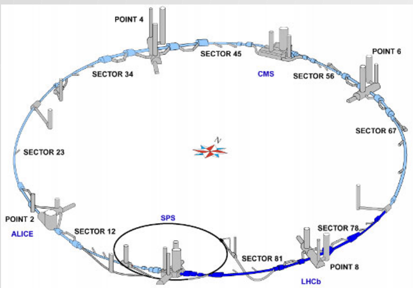
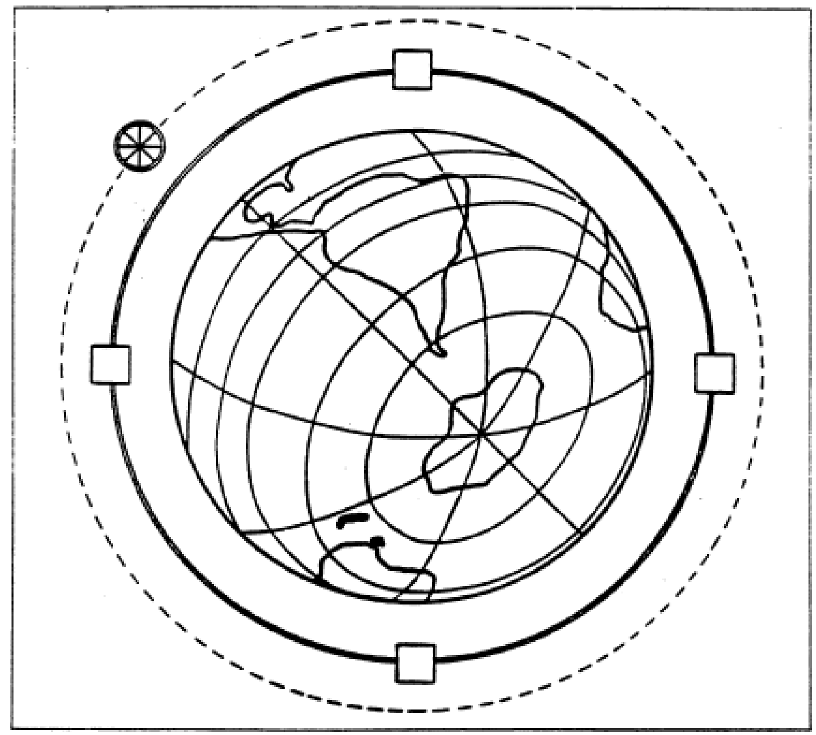
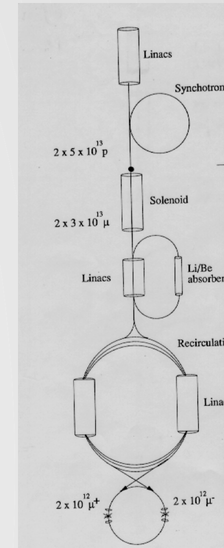




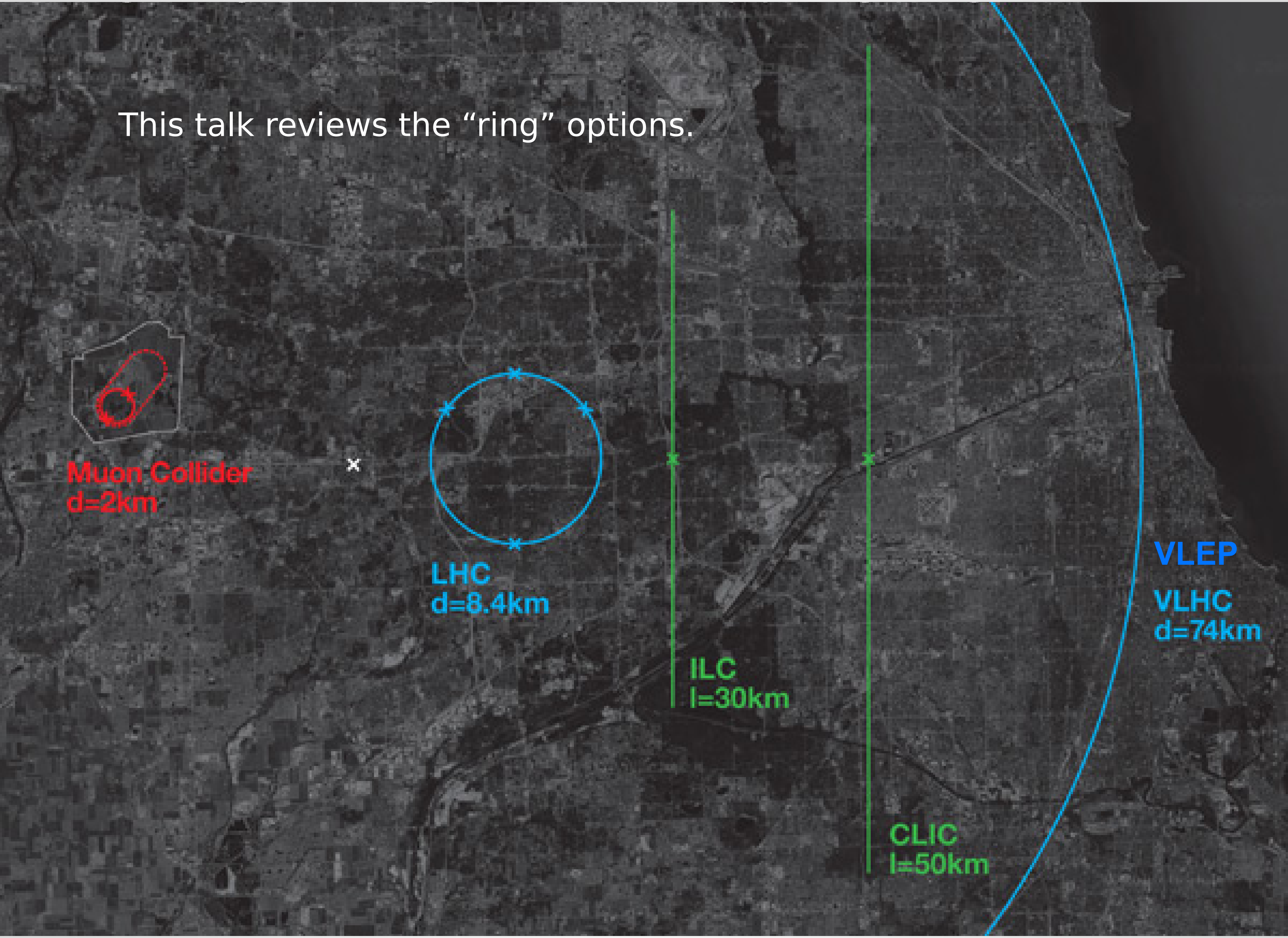
From a 1954 Slide by Enrico Fermi, University of Chicago Special Collections.



John Byrd
Center for Beam Physics,LBNL

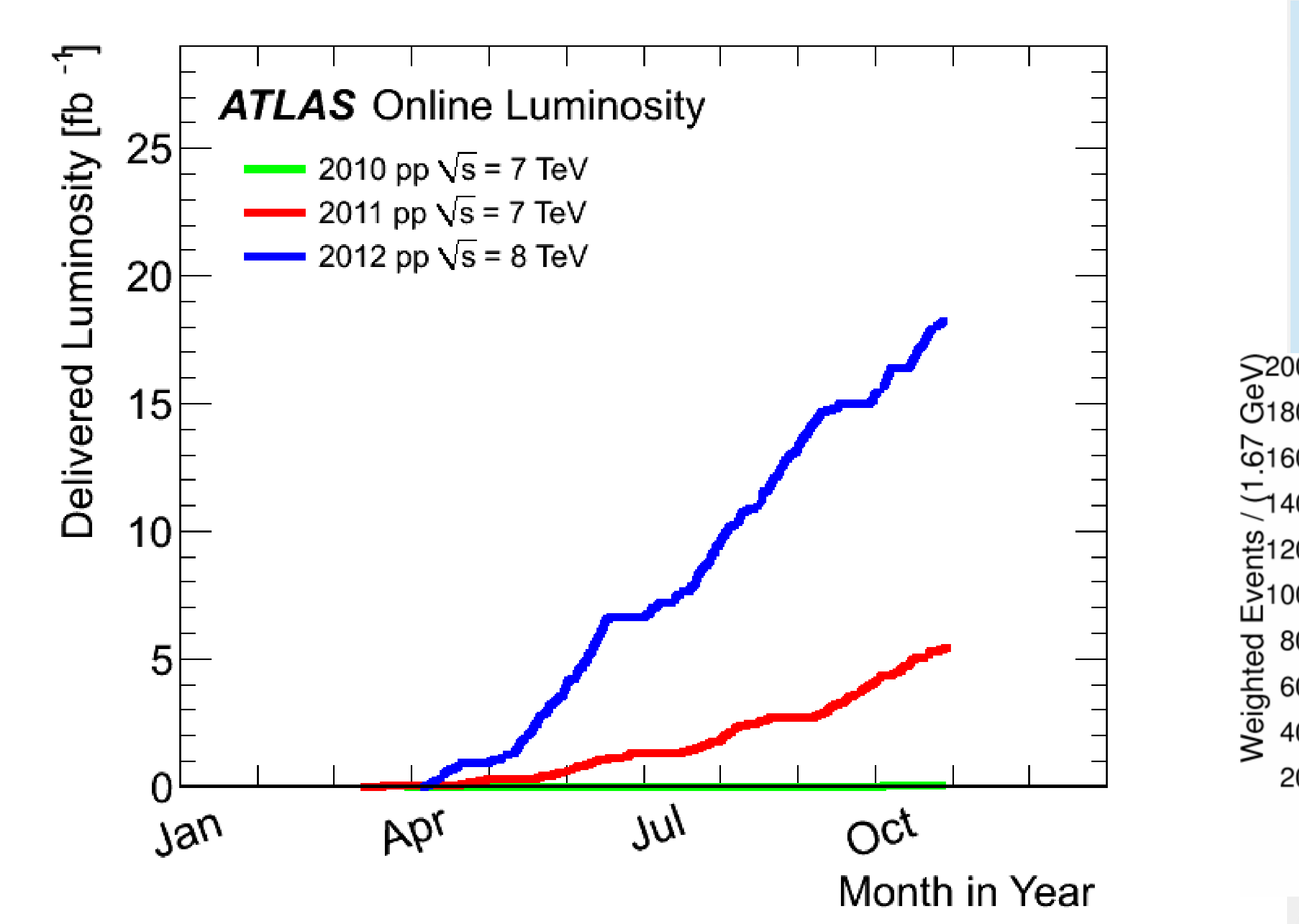
Slides from: Mike Lamont, Lucio Rossi, R. Aleksan, Frank Zimmermann, Mark Palmer

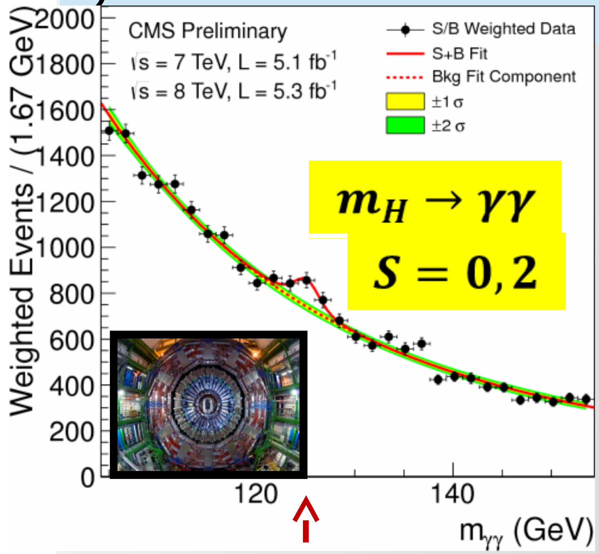
This talk reviews the “ring” options.



LHC Status: Integrated luminosity 2010-2012

201 0	Commissioning
201 1	Exploring the limits
201 2	Production+





3.5 TeV	5.6 fb-1
4 TeV	~21 fb-1

Never stop exploring

Summary

$$L = \frac{N^2 k_b f}{4\pi\sigma_x\sigma_y} F = \frac{N^2 k_b f \gamma}{4\pi\varepsilon_n \beta^*} F$$

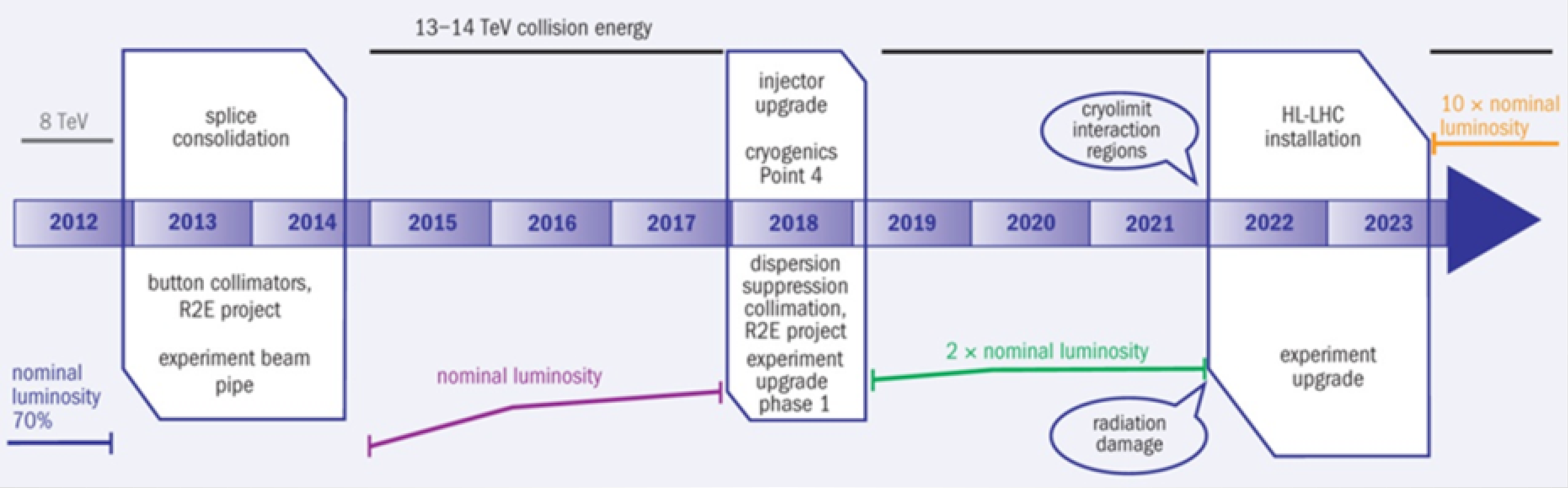
- Number of bunches/bunch spacing – move to 50 ns
- Bunch intensity
  - Move to nominal bunch intensity, and beyond with double batch 50 ns – and the LHC can take it
- Total intensity limits (now at 70% nominal with 50 ns)
- Emittance
  - 67% of nominal
- Beta* & aperture
  - Use of available aperture and tight collimator settings – opened the way to the squeeze to 60 cm

All this not without its

Limitations

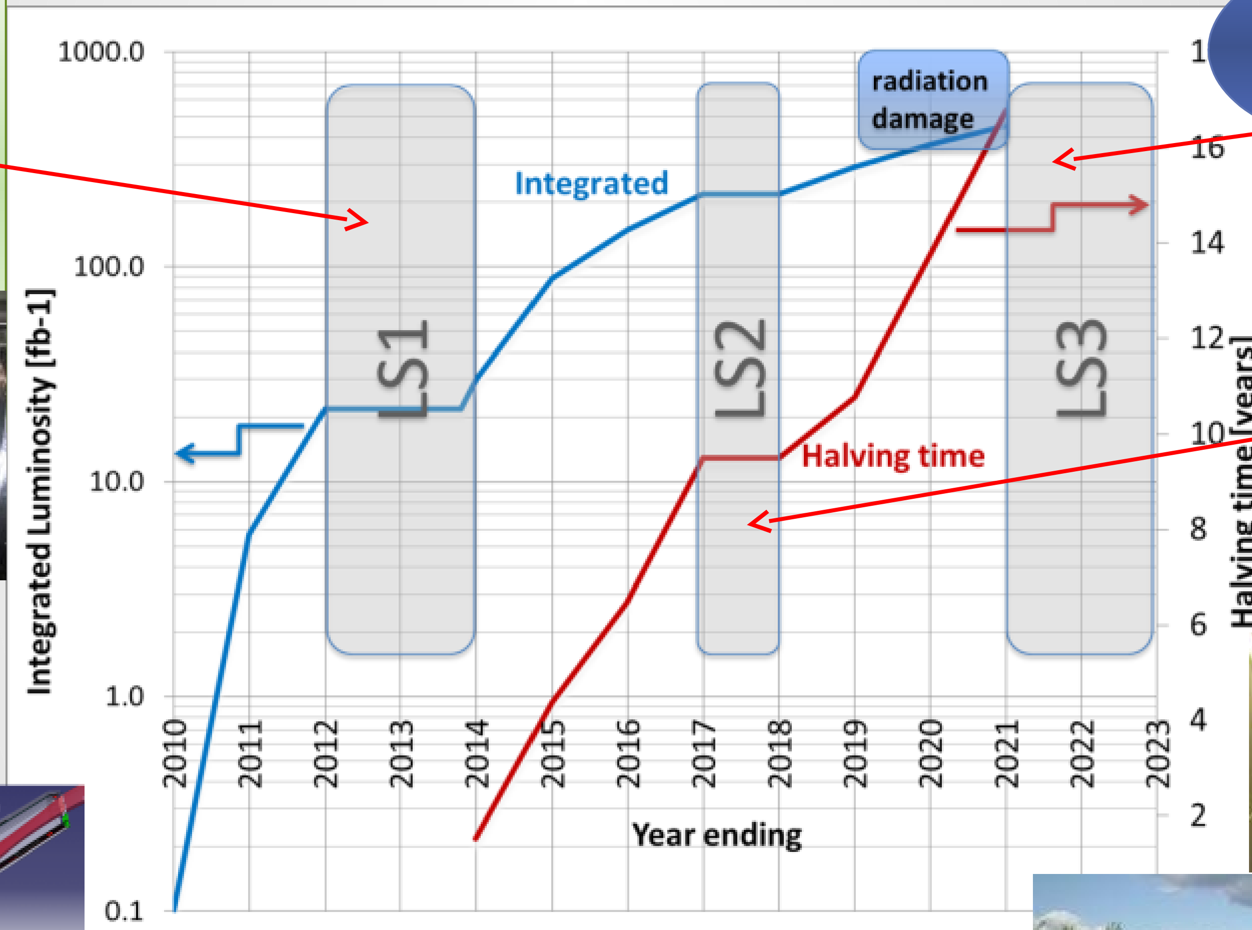
- Instabilities:
  - concerted program to understand and combat intermittent instabilities at end squeeze and going into collisions with high-bunch intensities
  - Octupoles, high chromaticity, transverse damper, beam-beam
  - Now only present on few bunches, one beam, one plane, but worry in long term…
- Vacuum instabilities, e-cloud etc.
  - Non-conformities (installation, design) – thorough review ongoing
- Emittance blow-up through the cycle
  - it’s a mystery!
- Overall, LHC has had excellent performance with extremely promising future.

LHC Upgrade Plan



Performance & Technical (Consolidation)

Shut down to fix interconnects and overcome energy limitation (LHC incident



Full upgrade

Shut down to overcome beam intensity limitation (Injectors, collimation and

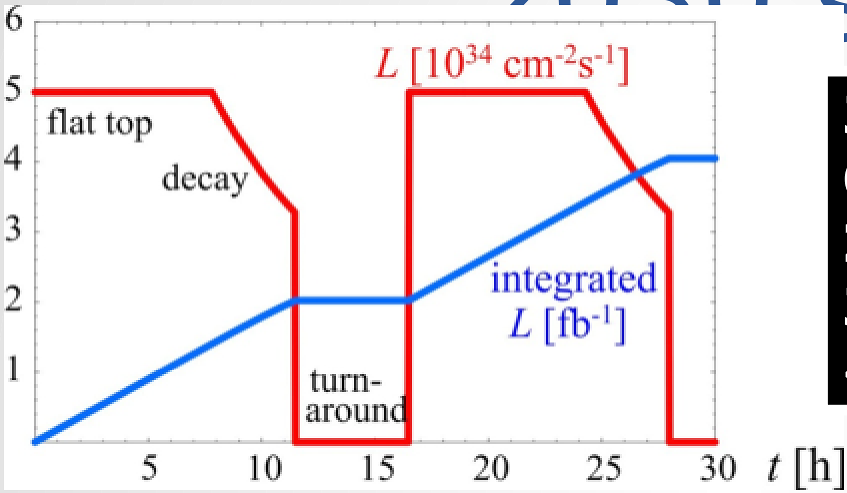
HiLumi: Two branches (with overlap)

- **Enhanced Consolidation upgrade (1000-1200 fb-1)**
  - Magnet rad. damage and enhanced cooling
  - Cryogenics (P4, IP4,IP5) with separation Arc form RF and from IR
  - Collimation
  - SC links (in part)
  - QPS and Machine Prot.
  - Kickers
  - Interlock system

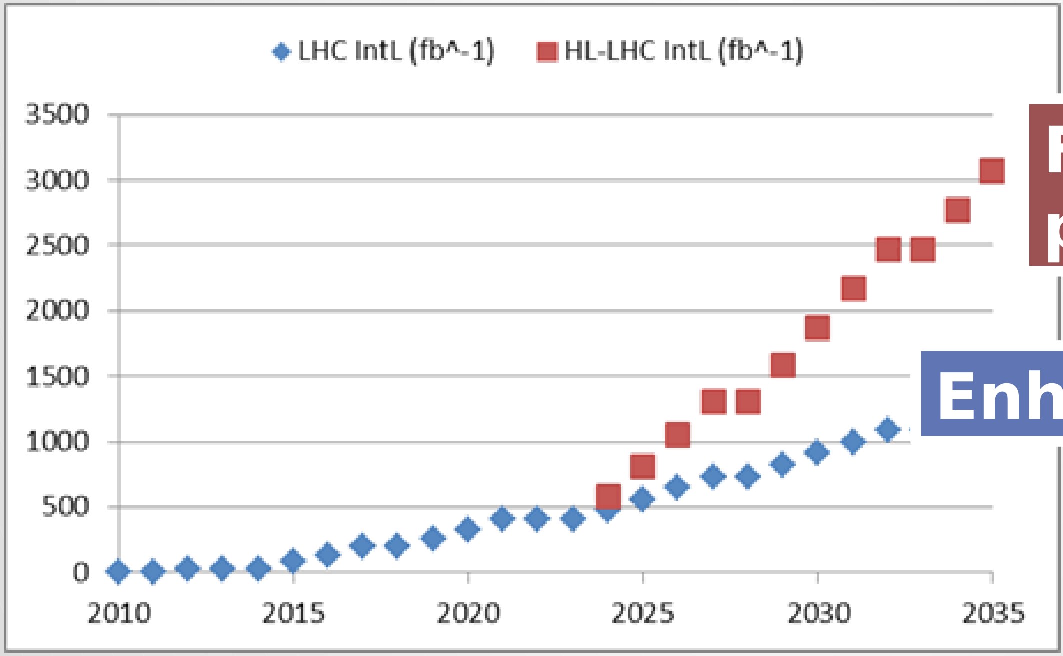
- **Full performance upgrade (3000 fb-1)**
  - **Maximum low-beta Quads aperture**
  - **Crab Cavities**
  - **HB feedback system (SPS)**
  - Advanced collimation systems
  - E-lens (?)
  - SC links (all)
  - R2E and remote handling for 3000 fb-1

LBNL involvement

Final goal : 3000 fb-1 by 2030's...



3 fb-1 per day
60% of efficiency
250 fb-1 /year
300 fb-1/year as «ultimate»



Full project

Enhanced consolidatio

LEP3 and TLEP

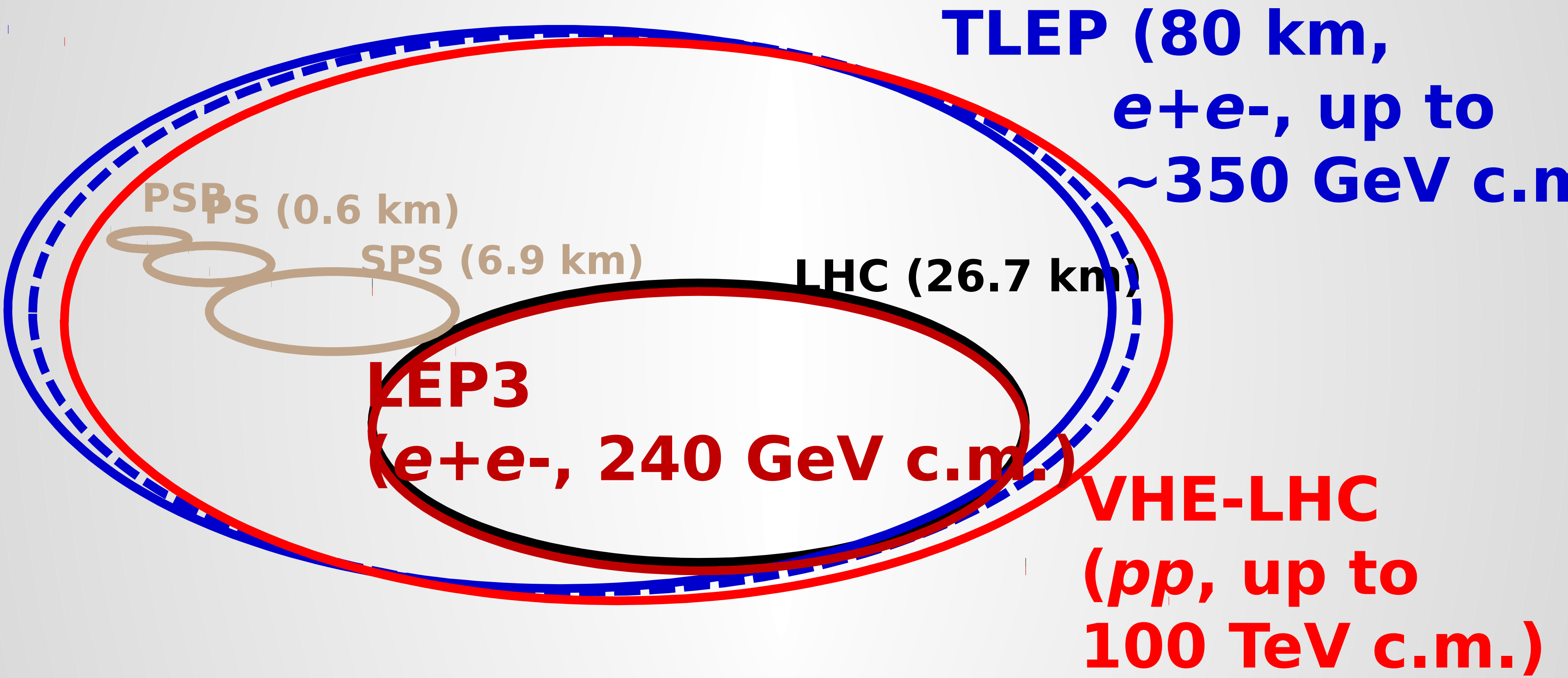
Frank Zimmermann

HF2012, FNAL, 15 November 2012

Thanks to R. Assmann, P. Azzi, M. Bai, A. Blondel, H. Burkhardt, A. Butterworth,
Y. Cai, A. Chao, W. Chou, P. Collier, J. Ellis, M. Fitterer, P. Janot, M. Jimenez, M. Klute, M. Koratzinos, A. Milanese, M. Modena, S. Myers, K. Ohmi, K. Oide, J. Osborne,
H. Piekarz, L. Rivkin, G. Roy, D. Schulte, J. Seeman, V. Shiltsev, M. Silari, D. Summers, V. Telnov, R. Tomas, J. Wenninger, U. Wienands, K. Yokoya, M. Zanetti, ...

work supported by the European Commission under the FP7 Research Infrastructures project EuCARD, grant agreement no. 227579

circular Higgs factories at CERN & beyor



o: ***e*± (200 GeV) – *p* (7 & 50 TeV)** collisions

- *a long-term strategy for HEP!*

two options

- installation in the LHC tunnel "LEP3"

  + inexpensive (<0

  + tunnel exists

  + reusing ATLAS and CMS dete

  + reusing LHC cryo

  - interference with LHC and HL-LHC

- new larger tunnel "TLEP"

  + higher energy reach, 5-10x higher luminosity

  + decoupled from LHC/HL-LHC operation & construction

  + tunnel can later serve for HE-LHC (factor 3 in energy from tunnel alone) with LHC remaining as injector

  - 4-5x more expensive (new tunnel, cryoplants, detectors)

- Similar concepts at KEK (SuperTristan), IHEP (CHF), Fermilab
  - All based on ~200 MW power limit.

LEP3, TLEP

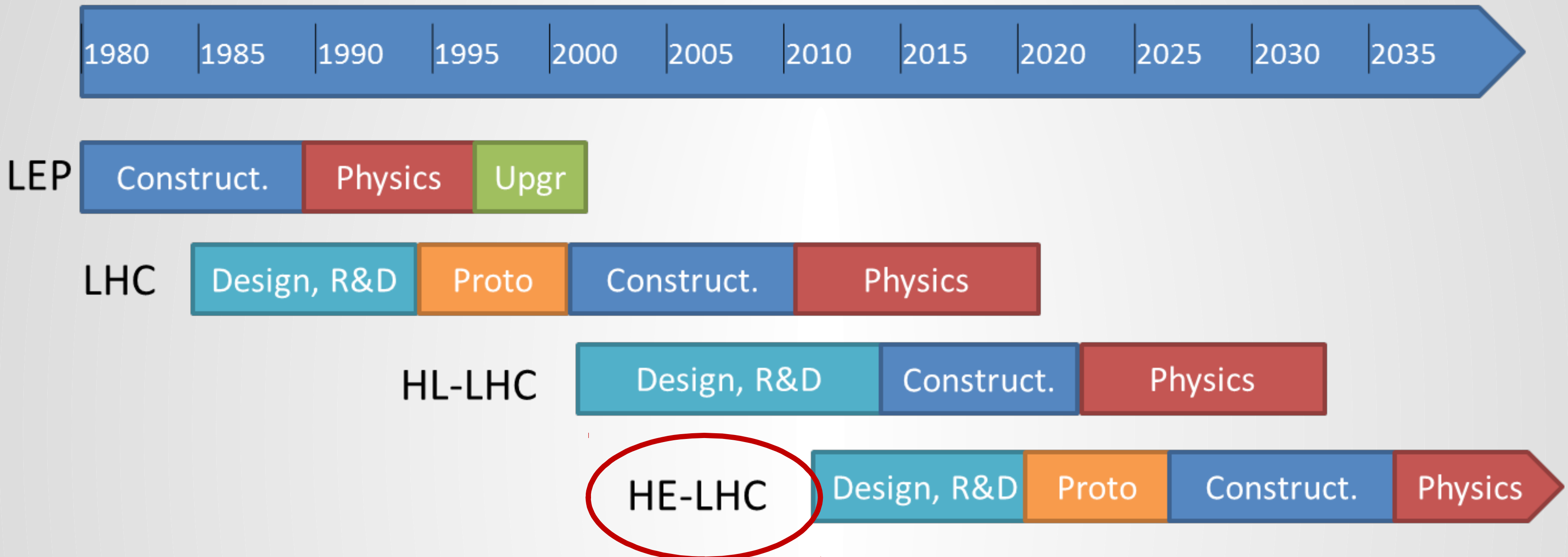
(e⁺e⁻ -> ZH, e⁺e⁻ → W⁺W⁻, e⁺e⁻ → Z,[e⁺e⁻→ $t\bar{t}$])

key parameters

	LEP3	TLEP
circumference	26.7 km	80 km
max beam energy	120 GeV	175 GeV
max no. of IPs	4	4
luminosity at 350 GeV c.m.	-	0.7x1034 cm-2s-1
luminosity at 240 GeV c.m.	1034 cm-2s-1	5x1034 cm-2s-1
luminosity at 160 GeV c.m.	5x1034 cm-2s-1	2.5x1035 cm-2s-1

at the Z pole repeating LEP physics programme in a few minutes…

The super-exploitation of the CERN complex: Injectors, LEP/LHC tunnel, infrastructures



Either using existing LEP/LHC tunnel to reach 26-32 TeV collisions

Or build (or reuse) a 80km tunnel to reach 80-100 TeV collisions

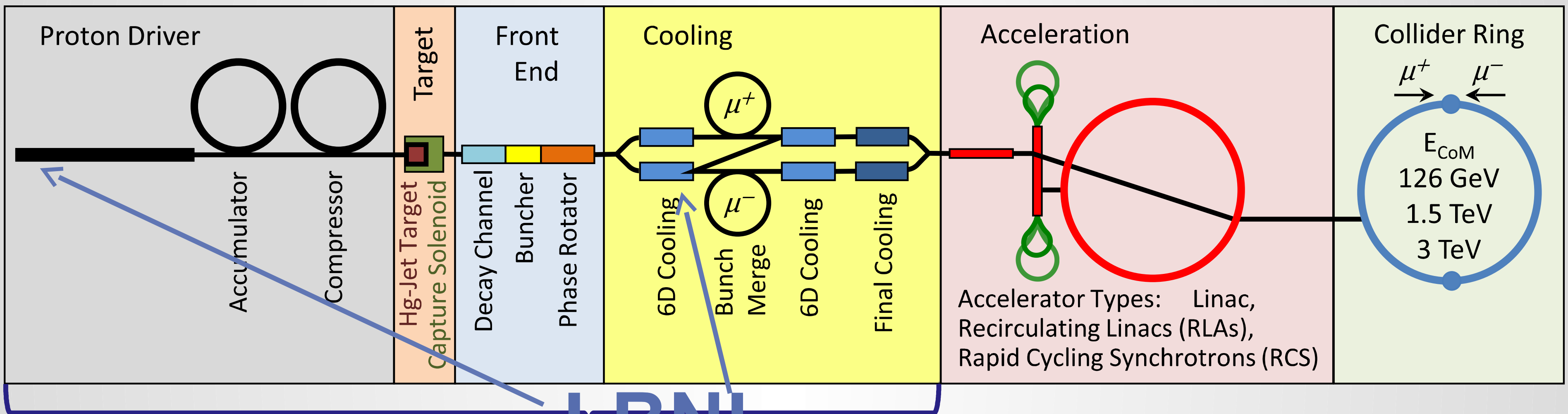
oth cases, SC challenge to develop 16-20 Tesla magn

Workshops

- LEP3 Day, CERN, 18 June 2012
- European Strategy Mtg, Sept 2012, Kracow
- Higgs Factory 2012, Fermilab, Nov 2012
- UCLA Higgs Factory Collider Workshop, Mar 2013
- Snowmass 2013, July 2013 and associated workshops
- ...

Muon Collider Concept

Muon Collider Block Diagram



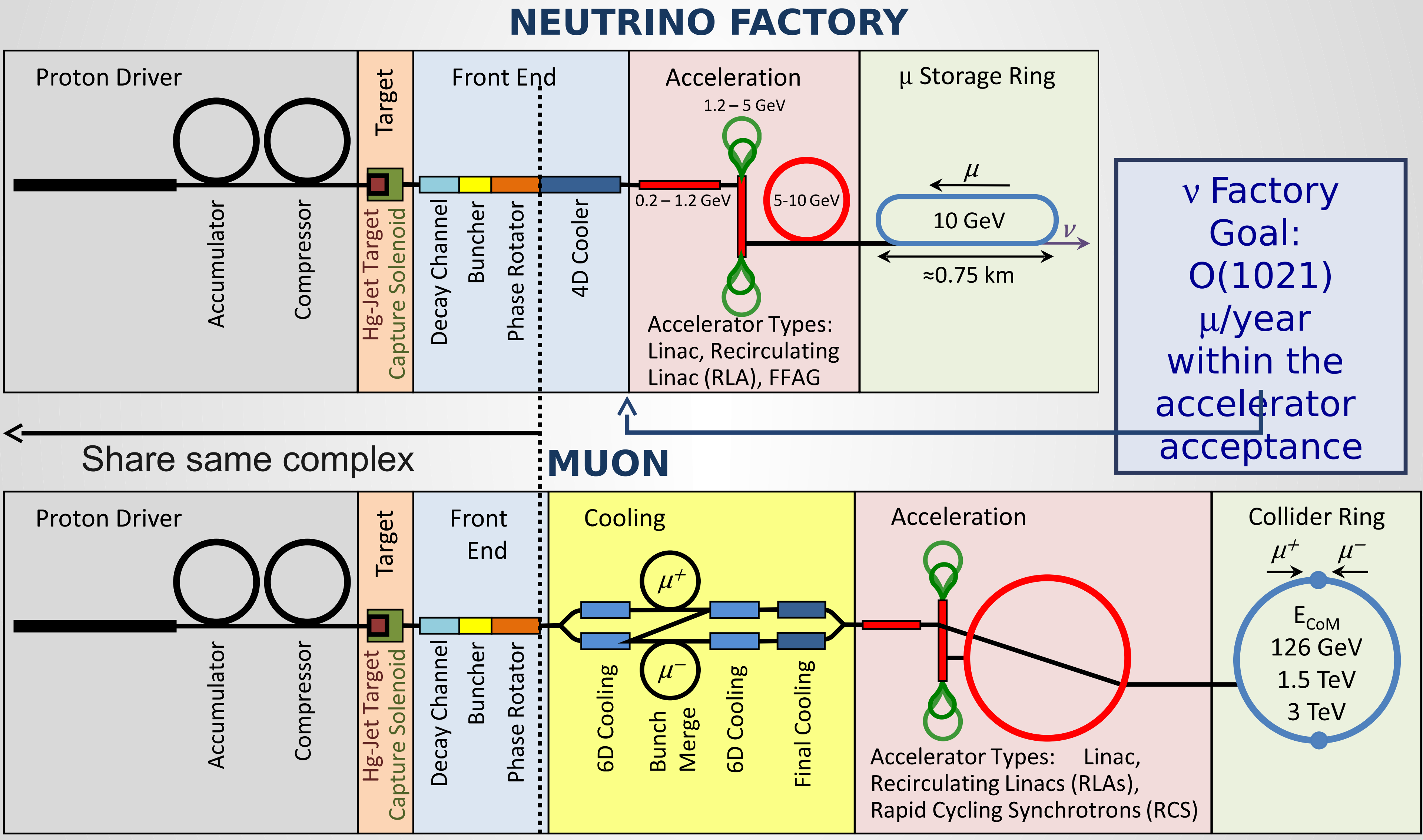
LBNL involvement

Proton source:
For example PROJECT X at 4 MW, with 2±1 ns long bunches

Goal:
Produce a high intensity μ beam whose 6D phase space is reduced by a factor of >106 from its value at the production target

Collider: √s = 3 TeV
Circumference = 4.5km
L = 3×1034 cm-2s-1
μ/bunch = 2x1012
σ(p)/p = 0.1%
ε⊥N = 25 μm, *ε*//N=72 mm
*β** = 5mm
Rep. Rate = 12 Hz

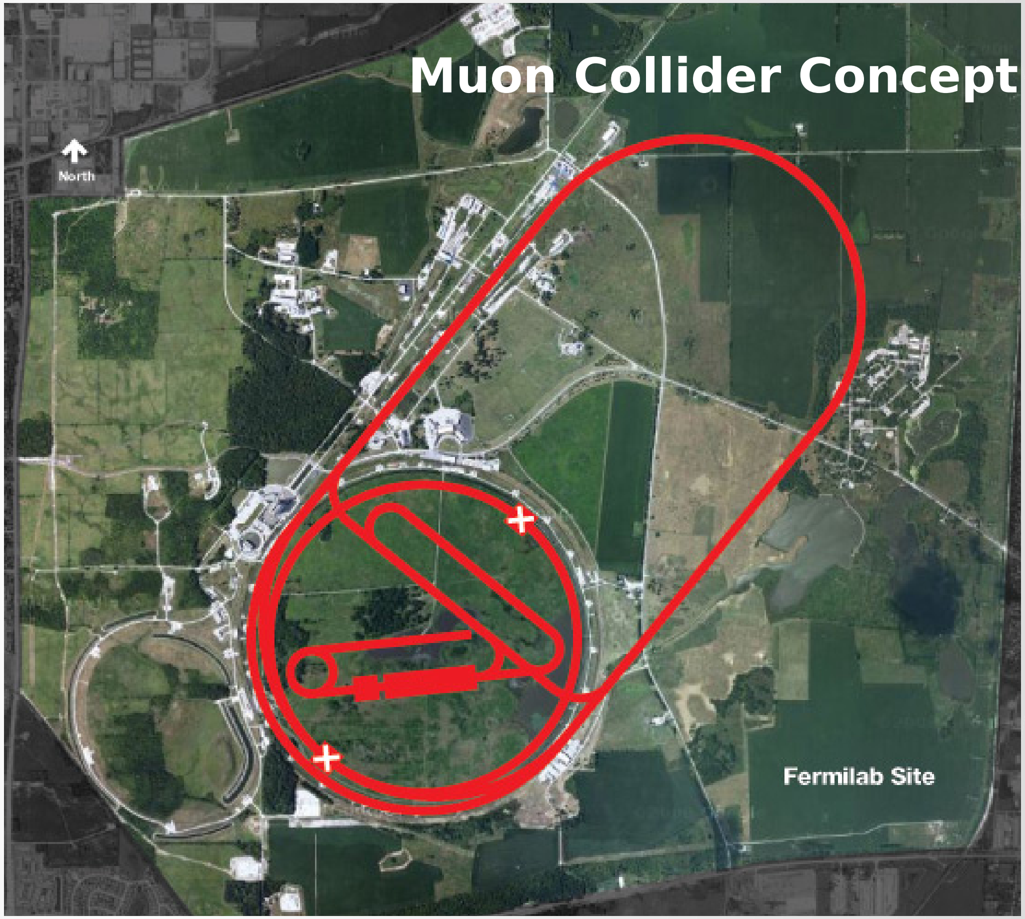
Muon Collider - Neutrino Factory Comparison



Muon Accelerator Program

- MAP is working towards a 6-year Feasibility Assessment in 2 phases:
  - Feasibility of key concepts needed for a Muon Collider
  - Deliver U.S. contributions to the International Design Study for a Neutrino Factory
  - Provide the foundation for a facility that can support unsurpassed Intensity and Energy Frontier research

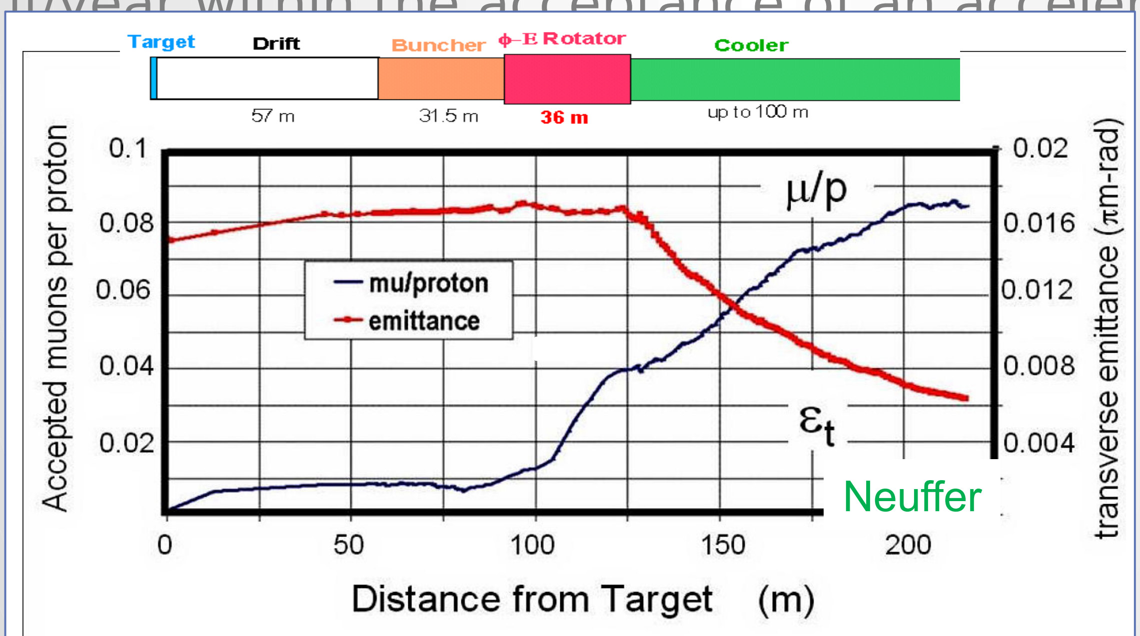
a Enable an informed decision on the path forward by the HEP community

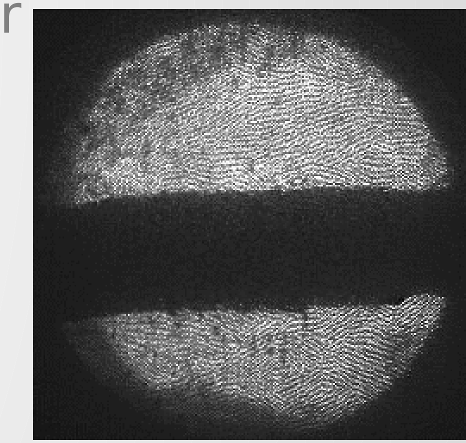


A challenging, but promising, R&D program lies ahead!

Technical Challenges: Target & Front End

- Tertiary production
  - Target Demonstration:
    MERIT Experiment with Hg Jet
    Capable of 8MW of beam power
    @ 70 Hz repetition rate
  - Cooling Beams to provide O(1021)
    μ/year within the acceptance of an accelerator

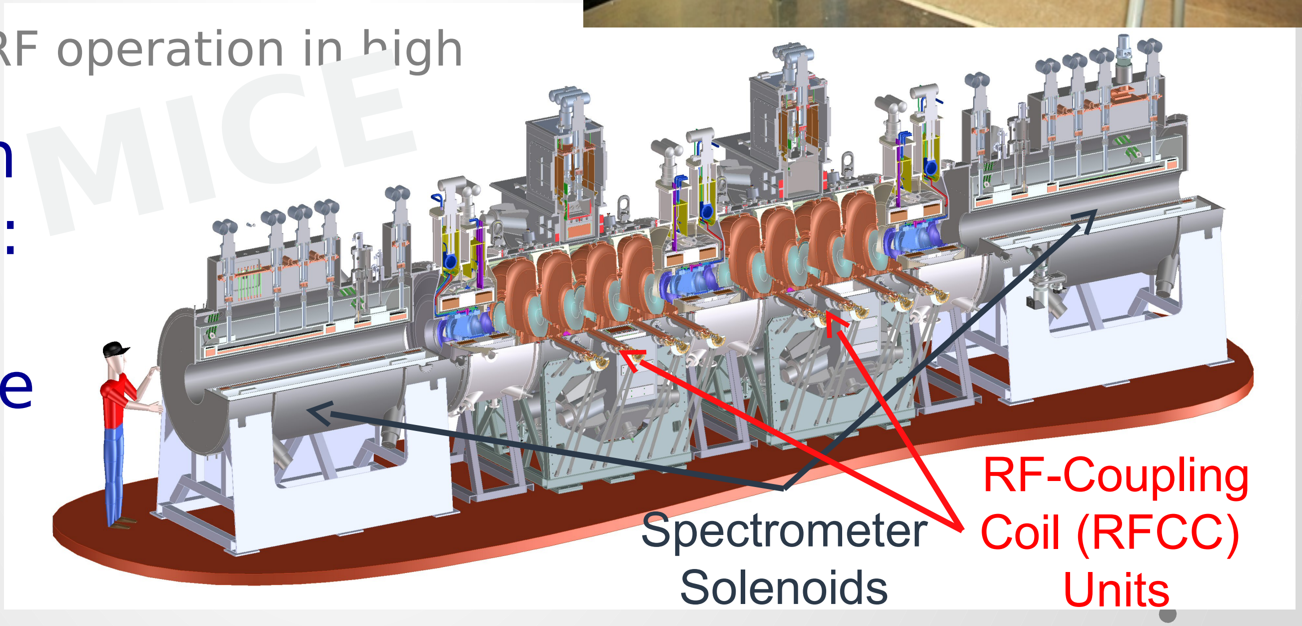




Technical Challenges: Cooling

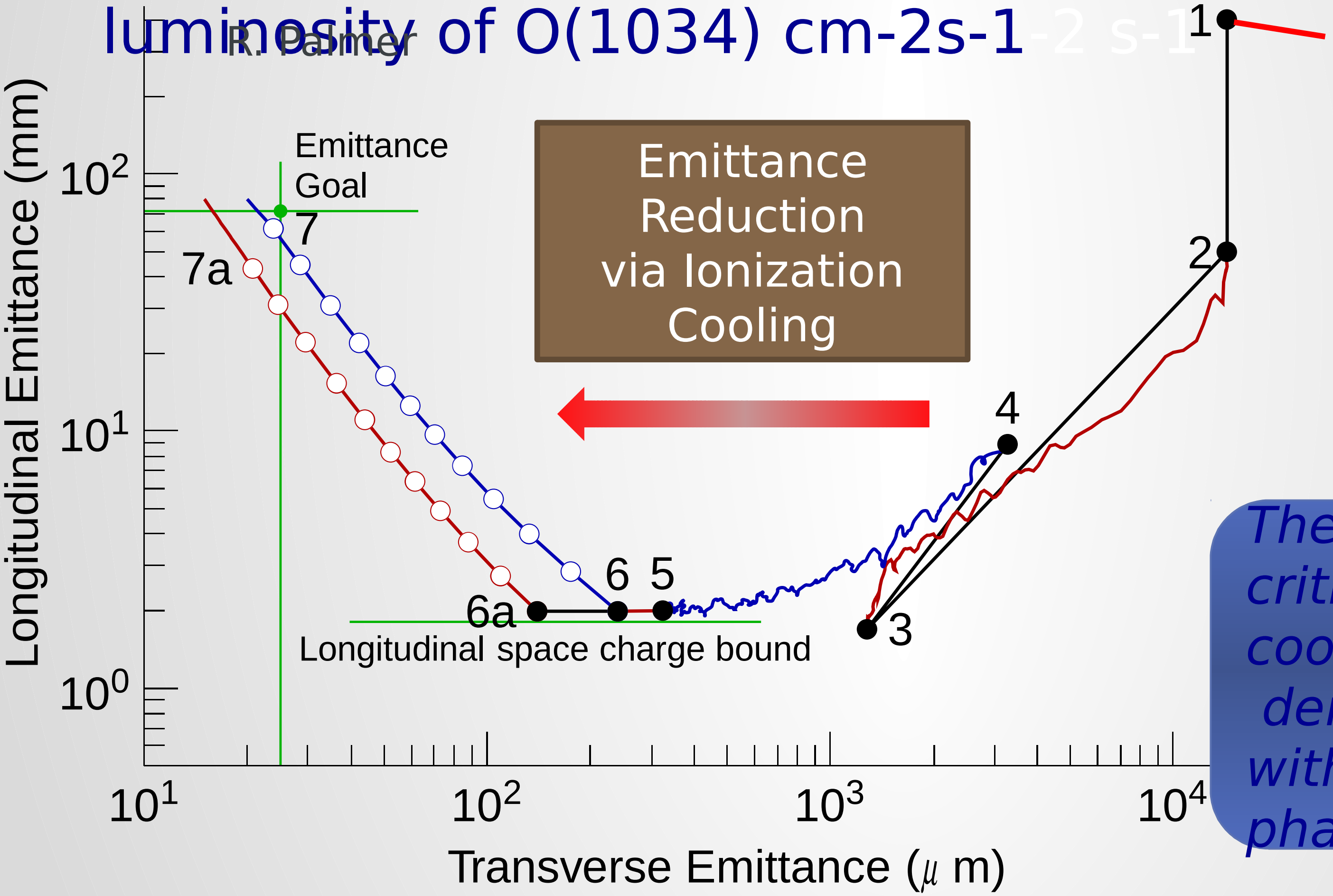
- Muon Cooling a Ionization Cooling
  - dE/dx energy loss in materials
  - RF to replace *plong*
  - Strong focusing and a large accelerating gradient to compensate for the energy loss in absorbers
  - Large B- and E-fields superimposed
  - Must understand RF operation in high magnetic fields

The Muon Ionization Cooling Experiment: Demonstrate the method and validate our simulations



Technical Challenges: Cooling

- Development of a cooling channel design to reduce the 6D phase space by a factor of O(106) → MC luminosity of O(1034) cm-2s-1-2 s-1



Some components beyond state-of-art:

- Very high field HTS solenoids (30-40 T)
- High gradient RF cavities operating in multi-Tesla fields

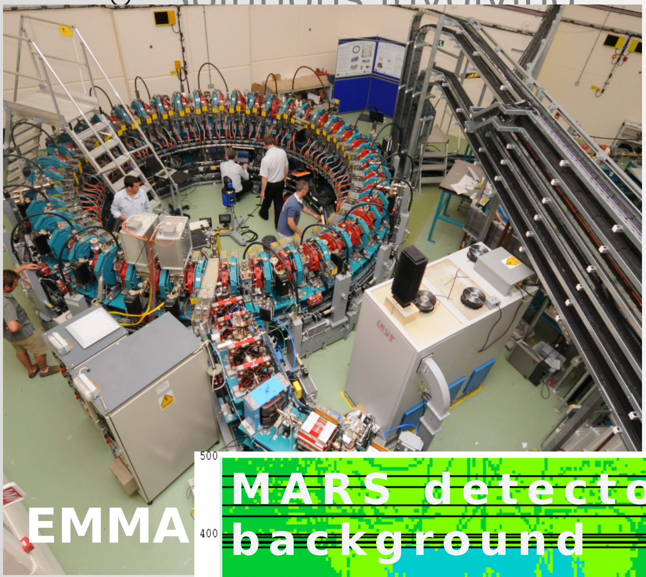
The program targets critical magnet and cooling cell technical demonstrations within its feasibility phase.

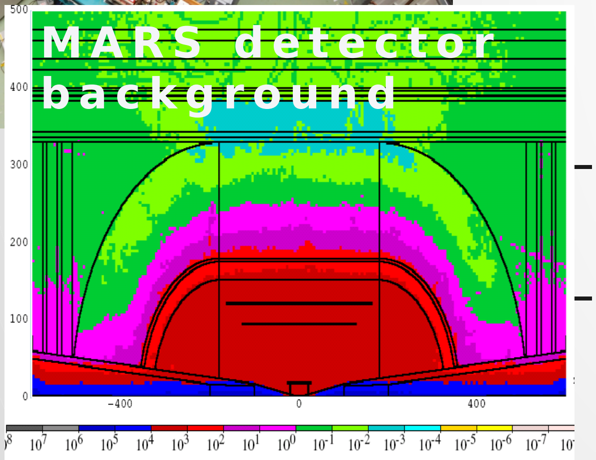
Technical Challenges: Acceleration and Collider

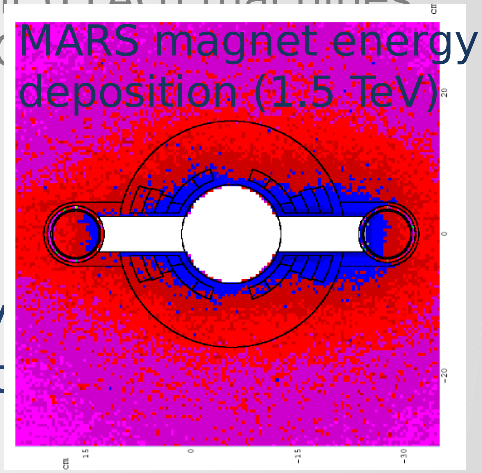
- Muons require an ultrafast accelerator chain

  a *Beyond the capability of most machines*

  - Solutions involving:
    - Superconducting Linacs
    - Recirculating Linear Accelerators (RLAs)
    - Fixed-Field Alternating-Gradient (FFAG) machines
    - Rapid Cycling Synchrotrons (RC
    - Hybrids

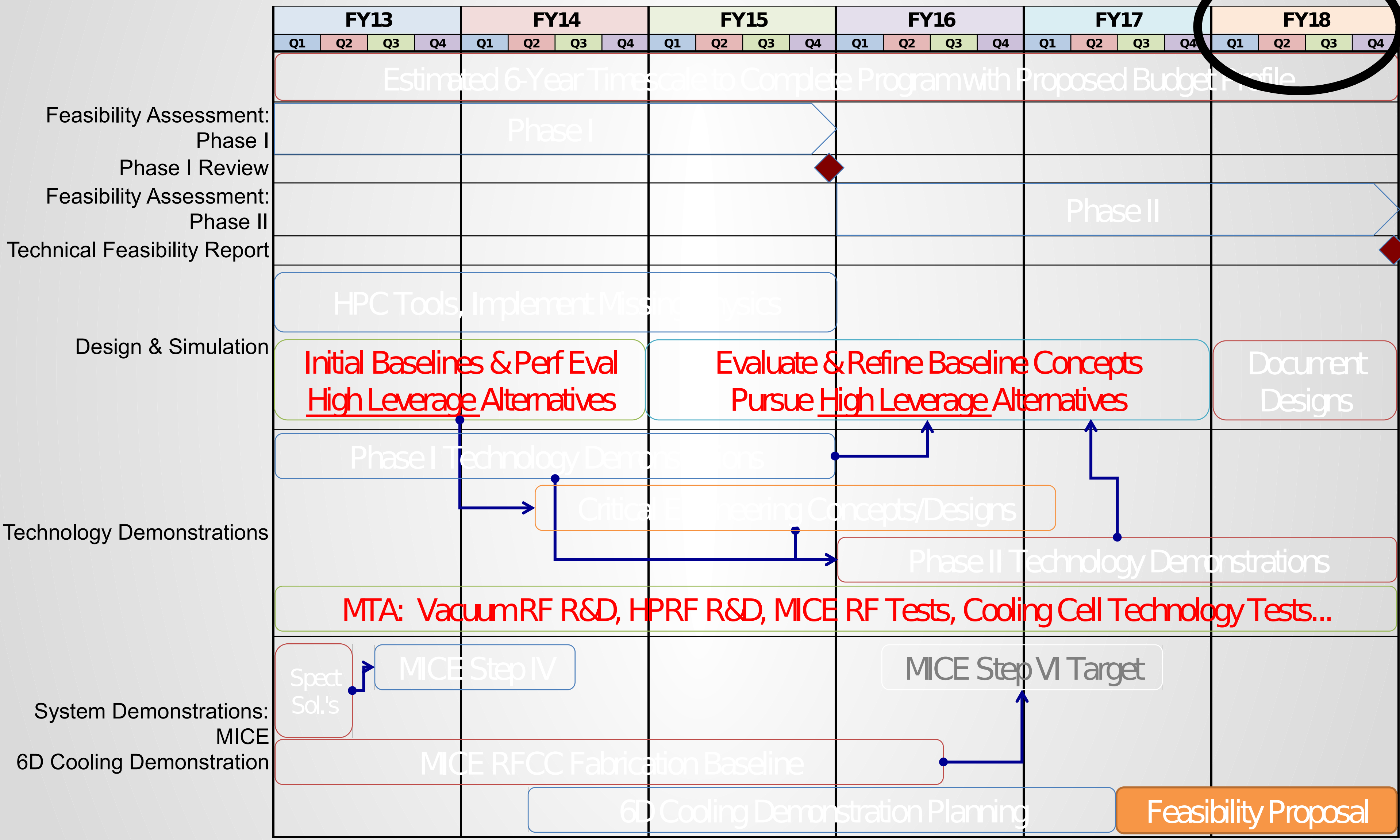


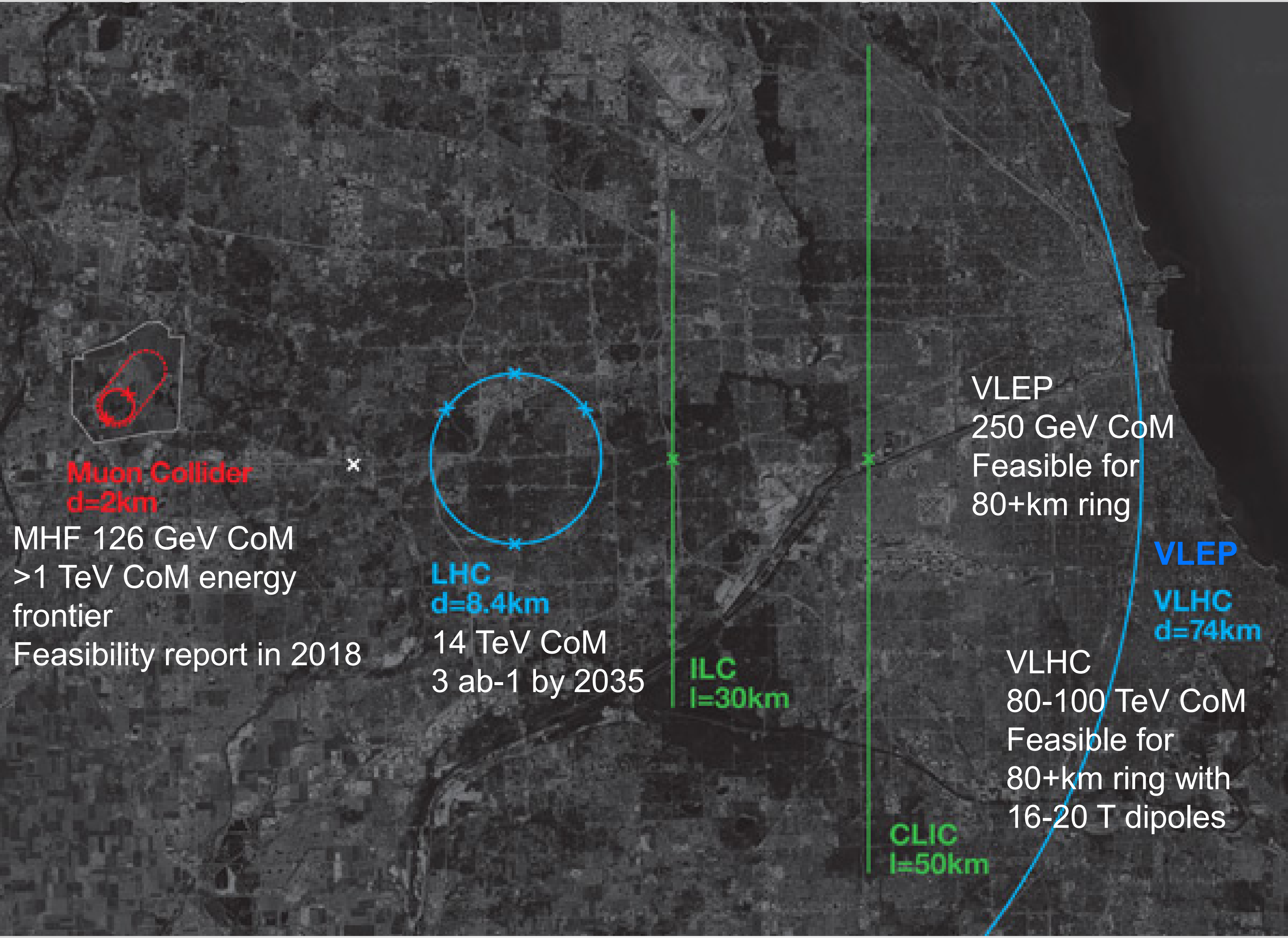




- Collider and Detector
  - Emittances are relatively large, but muons circulat for ~1000 turns
  - High field dipoles and quadrupoles operating in high-radiation environment
  - Challenging detector backgrounds and shielding issues

The Feasibility Assessment




Muon Collider
d=2km
MHF 126 GeV CoM
>1 TeV CoM energy
frontier
Feasibility report in 2018
LHC
d=8.4km
14 TeV CoM
3 ab-1 by 2035
ILC
l=30km
CLIC
l=50km
VLEP
250 GeV CoM
Feasible for
80+km ring
VLEP
VLHC
d=74km
VLHC
80-100 TeV CoM
Feasible for
80+km ring with
16-20 T dipoles